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"ment of Godfrey's Quadrant, and spoke to Mr. Grant as follows :
 "I am sorry, I am obliged to go out of town to morrow, as I
 "could wish to have some further conversation on this subject ; but
 "there is a gentleman of this city, the Rev Mr. Ewing, who
 "some time ago mentioned to me an improvement of a similar nature,
 "which he had made, and I believe he has engaged a workman to
 "finish a Quadrant for him, on the plan he has projected. Are
 "you acquainted with Mr. Ewing ? If not, I will bring you to-
 "gether, for I would wish you to compare your schemes, and to
 "have a conference with each other. Mr. Grant expressed his
 "desire to be acquainted with Mr. Ewing, and I accordingly in-
 "troduced them to each other, before I went on my journey

WILLIAM SMITH."

To the Rev. Mr. Ewing.

THESE things I have mentioned not from a solicitude about the invention, but to shew, that, what has often been supposed probable in affairs of this nature, has actually taken place in the present instance ; that men at the distance of many thousand miles might fall nearly upon the same inventions, about the same time, without any previous correspondence or acquaintance with each other.

J. E.

*An ESSAY on the Use of COMETS, and an Account of their
 LUMINOUS APPEARANCE ; together with some Conjectures
 concerning the Origin of HEAT.*

By HUGH WILLIAMSON, M.D

Read before the Society, Nov. 16th, 1770.

A COMET is a solid dark body revolving round the Sun in stated periods, receiving light and heat from the Sun. Comets revolve as other planets do in an ellipsis, one part of which is much farther from the Sun than another ; some of them are very eccentric ; that which appeared Anno 1680 was twelve thousand millions of miles from the Sun in aphelio, it was not half a million in perihelio. The period of the Comet which

appeared Anno 1758 is 75 years. That of 1661 is 120 years. And that of 1680 is 575 years. Though Comets doubtless move in an ellipsis, yet from the extreme length of their path, the small part that falls under our observation, the difficulty in determining the Comet's absolute distance or velocity, &c. we have obtained no certainty concerning the period of any Comet except the three I have mentioned, nor shall we ever determine their periods in all probability, except by a series of observations on the return of each particular Comet, which may require several thousands of years.

COMETS receive their light and heat from the Sun, for they appear to have no light of their own, and are thence invisible, except on their near approach to the Sun. In the year 1723, an Astronomer had the fortune to discover a Comet by means of his telescope before it was bright enough to become visible by the naked eye. The great Comet which appeared Anno 1743 seemed no larger than a star of the fourth magnitude when first discovered; as it came down towards the Sun it acquired a tail, and increased gradually in size and lustre till it obtained that amazing form with which it terrified half the world. As this Comet departed from the Sun, its tail decreased, it lost its brightness, till in a short time it became invisible; this has also been the fate of every other Comet; hence it is plain that their light, like that of other planets, is borrowed from the Sun.

HAVING just mentioned those general properties in which Comets evidently agree with other planets, I shall now try to account for that luminous train which attends them on their approach to the Sun, from which they are generally denominated Blazing Stars, and are supposed to differ essentially from every other planet or star. If I should be singular in any part of my opinion on this subject, I presume I shall be indulged, since it is matter of mere hypothesis.

COMETS are not Blazing Stars, they do not burn at all, nor is there any remarkable heat in that tail which has so often terrified the nations, and been thought to portend dissolution to the world itself. The Comet of 1743 had acquired a tail some thousands of miles long above two months before he passed

passed the Sun, while he was yet three hundred millions of miles from the Sun. Surely this could not be a flame of fire kindled by the Sun, else Comets take fire in a place where every drop of water on this globe would instantly freeze. There is no greater reason to think that Comets burn by their own heat, since their tail, whatever it be, as well as their light, evidently depends on the Sun, as we have already explained.

PHILOSOPHERS have differed greatly in their attempts to account for the tail of a Comet. One imagines that Comets are surrounded on all sides by a lucid fiery vapour, or atmosphere, which on account of the Sun's superior light, is only visible in the dark, whence we see no part of it but that which is in the shadow of the Comet on the side opposite to the Sun. According to him their atmosphere extends in all directions seventy or eighty millions of miles, for some Comets have appeared with a tail of that length, so that from the near approach of Comets to the earth we must frequently have been enveloped in that same lucid atmosphere.

FROM the extreme vicissitudes which Comets seem to endure, at one time penetrated with intolerable cold, at another time blazing with destructive heat, some have irreverently conjectured that they were designed as a place of future residence for the unhappy transgressors in this state, and thus vainly suppose that fifty or an hundred worlds were created for the sake of punishing the inhabitants of this little globe. It is sufficient to have mentioned such conjectures.

THE great Sir Isaac Newton was of opinion, that Comets were designed, among other purposes, to nourish and refresh this earth and all the neighbouring planets. He imagined that by vegetation and putrefaction, a great deal of radical moisture is consumed or changed into earth; that the tail of a Comet is a thick vapour exhaled from the Comet by the heat of the Sun, which vapour is scattered through the planetary regions, and part of it being received within our atmosphere, occasionally supplies our loss of moisture.

WHATEVER

WHATEVER properties have been ascribed to heat, it seems very clear that evaporation cannot be performed unless by means of an atmosphere whereby the fluid is attracted, suspended and carried off. Therefore if we suppose that the earth and all the Planets are supplied with radical moisture from the Comets, we must also suppose, that the solar system is universally filled with an atmosphere sufficient for attracting and suspending fluids, which hypothesis would certainly destroy our present system of Astronomy. Besides this we may observe, that from the most accurate chymical analysis, there seems great reason to believe, that all the apparent changes in matter depend on combination and solution alone. That water may be combined with earth and again separated from it ; but, that since the Creation, this Globe has not sustained the absolute loss of one ounce of water, or gained one ounce of earth. Therefore we do not require any nourishment from the vapour of Comets.

I SEE no reason to doubt that Comets were created like this world, to be the residence of intelligent beings; some of them no doubt which travel to immense distances through the Heavens, may be inhabited by an order of beings, greatly superior to this short-lived race of mortals, and much better fitted for comprehending and admiring the works of their divine original, which they behold in greater perfection. One of the primary ideas we form of the Supreme Being is, that he is the source of life, intelligence and happiness, and delights to communicate them ; the earth we tread, the water we drink, and the very air in which we breathe, swarm with living creatures, all fitted to their several habitations. Are we to suppose that this little globe is the only animated part of the Creation, while the Comets, many of which are larger worlds, and run a nobler course, are an idle chaos, formed for the sole purpose of being frozen and burnt in turns. We cannot admit the thought ; the Comets are doubtless inhabited. The great vicissitudes of climate, is the only plausible objection that has been made to this opinion. The Comet of 1680 came within one hundred thousand miles of the Sun, but the Sun's whole diameter is more than seven hundred thousand miles. The Comet's heat was then supposed to have been two thousand times

times hotter than red hot iron ; but the same Comet was about twelve thousand millions of miles from the Sun, at his greatest distance, when it is supposed, that he perceived ten thousand times less heat than we usually enjoy. Hence it is supposed, that such a Planet could never afford a comfortable residence for rational creatures.

BUT here philosophers have taken for granted that the heat of every body is inversely as the square of its distance from the Sun, a proposition which I greatly suspect ; for I apprehend that it is contrary to experiment.

WERE heat a certain body proceeding immediately from the Sun, the quantity of heat in any space would doubtless be inversely as the square of its distance from the Sun. But I see no reason to believe that Heat comes from the Sun, while there is much reason to think that it does not. We perceive that Light comes from the Sun. We also perceive that Heat is produced in the bodies on which the rays of light fall, hence we are apt to confound Light and Heat together, though it be demonstrable that Light is not Heat and that Heat is not Light. So contracted is our knowledge of the primary constituent parts of bodies, that we cannot readily determine why any particular cause should not excite Heat with equal facility in all bodies. But we are taught by experience that different quantities are produced by the same cause, according to the medium on which it operates. It also appears that the particular aptitude of any body to be heated is nearly as the elasticity of that body, or the cohesion of its parts. Whatever produces a tremulous motion in the particles of any body, excites Heat in that body, and vice versa whatever excites Heat produces a tremulous motion in the particles of the body. Does Heat therefore consist in nothing else than the rapid vibrations of the minute particles of any body ? or is there an elementary principle of fire diffused through all bodies, which is only excited or brought into action by any cause which produces a tremulous motion in the particles of those bodies ? The latter seems most probable, though in solving the present hypothesis there is no difference whether Heat depends on the simple vibration of the particles of matter, or whether it depends

pends on the fire which was only brought into action by the vibration of those particles, provided it should appear that the Heat in every body is uniformly as the vibratory motion of the particles of that body.---This I apprehend is the case, and shall beg leave to mention such evidence as seems to render the matter at least very probable.

PHILOSOPHERS have enumerated five methods by which Heat is generated, viz. 1, by attrition, 2, chymical mixture, 3, fermentation, 4, inflammation, and 5, by the Sun. In all these cases it appears that the Heat depends on a vibratory motion which by one means or another is excited in the particles of the body.

1. HEAT is produced by attrition, or by the striking or rubbing of one body against another. In this case there can be no doubt that the Heat depends on the vibratory motion of the particles, hence bodies are soonest heated where the friction is considerable, provided the bodies have also a proper degree of elasticity. For the motion once communicated to the particles of an elastic body, are retained a considerable time, and increased by every succeeding stroke of the cause which put them into motion. The quantity of Heat produced in any body by friction, depends greatly on the body being fit to preserve the motion once communicated. Thus a saw fixed in a hand-vice so that it may long retain its tremulous motion, will soon be heated, whilst the file with which it is rubbed is not soon heated, being held in the soft unelastic hand, whereby the vibratory motion of its particles are immediately destroyed. The facility with which some bodies are heated before others, and with which the same body may be heated in one position rather than in another, abundantly prove that the quantity of Heat produced in any body by friction will not be as the motion communicated, but as the strokes communicated, together with the number of vibrations retained and communicated in consequence of each stroke.

2. THE Heat which is produced by chymical mixture has been the subject of much speculation.---There are sundry bodies which joined together produce considerable Heat, as water with oil of vitriol; others produce cold, as salt of nitre with water.

water. Why should one union produce heat the other cold? It appears in general that all mixtures, properly so called, produce heat, all solutions produce cold. But in every mixture the bodies undergo a certain change in their qualities, whereas bodies undergo no change by solution. This may point out to us the true origin of heat in one case, and cold in the other. When two bodies have an attraction to one another, and the pores of the one body are so constituted as that the minute particles or atoms of the other body may penetrate into them, a general dissolution of the constituent parts of the body must ensue, the minute particles being rent asunder by the attractive force of the parts; such dissolution of the constituent parts of a body necessarily alters the qualities of that body. We may easily perceive that in the rapid union of such bodies by which the minutest particles are rent asunder, the vibratory motion of those parts must be greatly increased. Hence the generation of heat by mixtures. Hence too the heat in such mixtures, seems to be in proportion to the number of particles, which in any body of a determined bulk, rush into union with and destroy the texture of one another.

IN solutions or cooling combinations no change is produced in the qualities of the bodies. Thus by a solution of nitre in water cold is produced, and the salt may be deposited from the water, or the water be evaporated, and neither of the bodies undergo the least change. In this case it appears, that there is no dissolution of the constituent parts of either body, by the attractive force of the other, or by the construction of their parts; but that the globules of one body adhere superficially to those of the other, and the particles of the fluid are simply charged with those of the solid, by which means the vibratory motion of the particles is diminished, whence cold is necessarily produced.

IT has been observed that spirit of nitre mixed with water produces heat, while the same spirit mixed with snow produces the most intense cold. This may be probably urged as an objection to the above theory of heating and cooling combinations, under the apprehension that snow being nothing else than frozen water, should on these principles produce the same

effects, on combination with any third body. But it must be observed, that one is a mixture, the other a solution. Water joined with spirit of nitre produces a mixture, the bodies undergo a change of qualities, and heat is generated. Pour the spirits of nitre into snow and nothing will follow, at least nothing has followed but a solution of the snow in the spirit. For these experiments have always been made when the temperature of the spirits was much below the freezing point of water, so that the snow could not be melted by such combination. Hence there being no intimate union of the parts, nor any thing else than a proper solution, cold was generated as in all similar cases.

3. HEAT produced by fermentation or putrefaction, may be accounted for in the same manner as that produced by chymical mixture, there being no doubt that new mixtures are constantly forming in every putrescent or fermenting body.

4. HEAT which is produced, by inflammation seems also to depend on the chymical mixture of bodies. In all bodies which blaze there is found an acid and mephitic air, which seem to abound in those bodies in proportion to their different degrees of inflammability. The separation of these two bodies constitutes a flame; this we observe can only be effected by means of a third body, *viz.* common air. The union of the acid with the water that is suspended in the air, and the union of the mephitic with the common air, produces two heating mixtures. Hence Heat is excited by flame.

5. HEAT is produced by the Sun: Does that Heat proceed immediately from the sun, as is generally supposed, or is it mechanically excited by the action of the rays of light? The latter is most probable. We have seen a variety of methods by which Heat is produced. They appear in different forms, but they all terminate in the same thing; they are different methods of exciting a tremulous motion in the particles of the body. By some of them the most intense Heat is produced, and yet in no case is there any actual addition of fire. When Heat is excited by the Sun, there is also a tremulous motion excited in the particles of the body, they are expanded,

expanded, &c. The phenomena resemble those of Heat excited by other means, whence it seems unphilosophic to suppose that there should be an accession of fire in this case more than in the others. I therefore suppose that *all the heat which is caused by the Sun, depends on a tremulous motion excited by the rays of light, in the particles of the body which is heated.* Hence it will follow that *the heat of any body will not be according to its distance from the Sun, but according to the fitness of that body, to retain and propagate the several vibrations which are communicated to its particles by the rays of light.* Hence it is that the air which is very elastic, when well compressed by the weight of the incumbent atmosphere, will receive a great degree of Heat near the surface of the earth, while the light thin air whose particles are removed to a considerable distance, as on the top of a high mountain, is always in a freezing state within the torrid zone.

LET us see how this theory of the generation of Heat may be subservient to the inhabitants of the Cometary worlds.

IT is evident that Comets are surrounded with an atmosphere very different from that of our globe; the height of our atmosphere is hardly supposed to exceed 60 or 70 miles, while that of a Comet is frequently 8 or 10,000 miles. Why should they have such a weight of atmosphere more than us? This is doubtless subservient to some very extraordinary purpose. We may also suppose with great probability, that the atmosphere of a Comet differs greatly from ours. The particles may be smaller, more subtile, elastic, and much more easily heated, whence the Sun's rays may be enabled to warm such an atmosphere compressed together by the weight of eight or ten thousand miles, at a distance from the Sun, in which we should perceive the most intense cold. This will explain the manner in which the inhabitants of a Comet may be sufficiently warm at their greatest distance from the Sun; but if they were proportionably heated on their nearest approach to the Sun, their summer heats would be intolerable; but this must certainly be the case if their atmosphere were in a permanent state, and continued in all seasons of equal density and weight. We are certain however from observation, that this is not the case; for as the Comet approaches the Sun, we can easily perceive its at-

mosphere greatly rarify'd, and thence rendered less fit for generating or retaining heat. But this is not the principal relief which Cometarians receive from the summer's Heat. The atmosphere of a Comet seems to undergo a change which is peculiar to itself. It is removed by the rays of light, and thrown off to a considerable distance behind the planet. It is demonstrable that the rays of light pass with amazing velocity, they travel above thirteen millions of miles in a minute; such amazing velocity multiplied into their weight, however small they be, must give them a considerale momentum or impelling force, which must be great in regions near the Sun; by this force they repel the extremely subtle and light particles of air, and drive them off to such a distance behind the Comet that their weight is hardly perceived on its surface. The atmosphere being thus repelled by the Sun's rays, and thrown as it were into a shelter behind the planet, will be there extended longitudinally in the form of a shadow, being very rare towards the top. Every particle near the surface of this immense stream of air must be illuminated by the refraction and reflection of the Sun's rays, whence they will exhibit the faint appearance of a blaze. Thus we are apt to imagine that a Comet is intensely hot, and that a prodigious flame proceeds from it, while we see nothing else than its enlightened atmosphere.

As the inhabitants of Comets are not pressed by day, when they come near the sun, with a thousandth part of the atmosphere which usually surrounds them, and which is doubtless the mediate and principal cause of their perceiving Heat, we may easily see how they may be tolerably cool at noon day, on their nearest approach to the Sun.

If we might form any conjecture concerning the life of a Cometarian, from the annual periods of the world which he inhabits, we should apprehend that he far exceeds the years of an antedeluvian. Or might we attempt to measure the continuance of this globe, from the length of time which will be necessary to bring the astronomy of Comets, as well as every other science to that perfection at which they must doubtless arrive, we should infer that a small portion of that time is yet elapsed. On which ever of these subjects the mind is suffered to stray for a few minutes, it will find sufficient subject of pleasing speculation.